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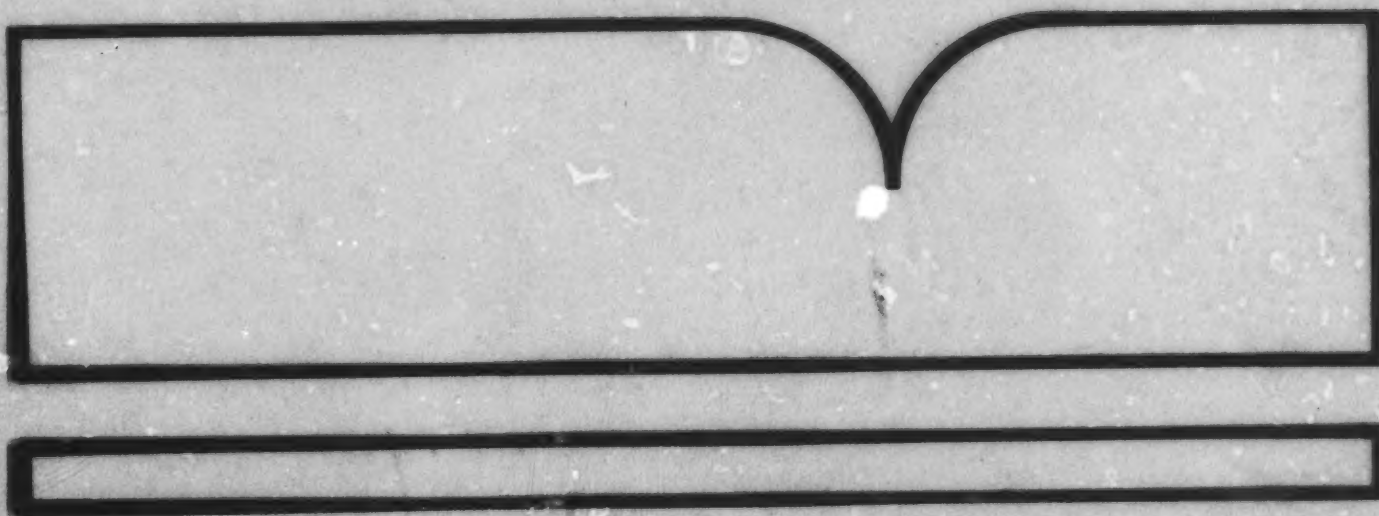
Removal and Treatment of
Contaminated River Bottoms
Field Demonstration

Envirex, Inc., Milwaukee, WI

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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REMOVAL AND TREATMENT OF
CONTAMINATED RIVER BOTTOMS: FIELD DEMONSTRATION

by

Robert W. Agnew
Envirex Inc. (A Rexnord Company)
Milwaukee, Wisconsin 53214

EPA Contract 68-03-0182

Project Officer

Joseph Lafornera

Oil and Hazardous Materials Spills Branch
Municipal Environmental Research Laboratory (Cincinnati)
Edison, New Jersey 08837

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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16. ABSTRACT This report documents the results of a project to remove creosote contaminated river bottom muds from the Little Menomonee River in Milwaukee, Wisconsin. Bioassays were conducted to determine toxicity levels for aquatic organisms, and primary skin irritation tests were performed to establish skin irritation levels in humans. Based on these tests, an allowable residual concentration of 500 mg/kg of hexane solubles was established. The removal/treatment system was designed and operated to accomplish the cleanup with an absolute minimum of damage to the shoreline and adjacent land. The system consisted of two floating, hydraulically powered river sweepers to dredge mud from the river bottom and pump the material to a presettling tank for removal of sand and other high density solids. The liquid from the presettler was chemically treated and clarified in a portable rubber sedimentation tank. The clarifier liquid was processed through mixed media filters and granular activated carbon filters and discharged back to the river. The sludge was thickened in a 18,025-liter (5000-gal) tank truck and disposed of in an industrial waste landfill. Approximately 1230 lineal meters (4040 lineal feet) of river bottom muds were cleaned and treated during this study, at a cost of \$100.70/lineal meter (\$30.80/lineal foot).		
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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report documents the results of a field demonstration to remove creosote-contaminated muds from a small stream, the Little Menomonee River, in Milwaukee, Wisconsin. River bottom muds from approximately 1230 lineal meters (4040 lineal feet) of river were removed and treated at a cost of about \$100.70/lineal meter (\$30.80/lineal foot). Based on analyses before and after treatment, about 76% of the creosote contamination was removed from this section of river. While this publication reports on removing creosote-contaminated muds from a small stream, the same techniques could be applied to cleaning up other sediments such as those contaminated with PCB or kepone.

Francis T. Mayo, Director
Municipal Environment Research
Laboratory

ABSTRACT

This report documents the results of a field demonstration to remove creosote-contaminated muds from a small stream, the Little Menomonee River, in Milwaukee, Wisconsin. River bottom muds from approximately 1230 lineal meters (4040 lineal feet) of river were removed and treated during this study at a cost of about \$100.70/lineal meters (\$30.80/lineal foot). Based on analyses before and after treatment, about 76% of the creosote contamination was removed from this section of river.

Before starting the clean-up, a residential level of 5000 ppm of creosote was established by bioassay tests to be safe for incumbent or potential aquatic species. Skin irritation tests were also carried out to use in protecting the personnel involved in the operation.

The field clean-up procedures were designed to minimize damage to the shoreline and the river. Two floating river sweepers equipped with suction heads were used to dredge mud from the river bottom and pump it to a land-based basin where it was allowed to settle. The liquid overflow was then treated with coagulants and clarified, passed through multi-media pressure filters and given a final polishing with granular activated carbon. The liquid was returned to the river while the sludges and solids were disposed of in a landfill.

This report was submitted in fulfillment of EPA Contract No. 68-03-0182 by Envirex Inc. under the sponsorship of the U.S. Environmental Protection Agency. Work was completed as of April 1975.

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This project was directed by Mr. Roy A. Johnson with assistance from many members of the Envirex staff.

SECTION 1

INTRODUCTION

The Little Menomonee River is a small, meandering stream located in northwestern Milwaukee County. The river is a tributary to the much larger Menomonee River that flows into Lake Michigan. The bottom muds and shore of the lower 5 miles of the Little Menomonee are laden with creosote. This material is thought to have been discharged into the river for many years as a waste product following its use as a preservation for wooden railroad ties. Creosote is a distillate of coal tar produced by high-temperature carbonization of bituminous coal (1). The substance is similar to oil in its appearance, but is heavier than water. Attention was brought to the dangers of this material in 1971 when a member of a citizens group engaged in cleaning the river had to be hospitalized with burns after coming in contact with the creosote in the river.

The U.S. Environmental Protection Agency (EPA) awarded first-phase contracts in July of 1972 to Envirex and Industrial Biotest Company to design and demonstrate feasible means of removing and treating a hazardous material such as creosote from river muds. The results of these first phase contracts are documented elsewhere (2).

This report documents the second phase of this contract--an attempt to remove the remaining contaminants from the river bottom and banks. Included are the results of this cleanup effort, toxicity and skin sensitivity tests, and suggestions for future cleanup efforts of this type.

SECTION 2

CONCLUSIONS

1. Bioassay and skin irritation studies established the following maximum levels of pollutant:

- a. To protect incumbent and potential aquatic fauna, the maximum creosote that may remain in the muds after cleanup must not exceed 5,000 ppm.
- b. To establish 24-hour residence zones of passage for incumbent or potential aquatic fauna, the maximum creosote that may remain in the muds after cleanup must not exceed 10,000 ppm.
- c. To prevent potential hazards to humans not sensitive to creosote, no scum-generating area may exceed creosote concentrations of 10,000 ppm after cleanup.

2. The cleanup system developed and demonstrated for this effort was capable of achieving the desired residual levels and restoring the quality of the river to the point where land and aquatic species long absent were again observed. Approximately 76% of the creosote contamination was removed from the cleaned section of the river.

3. The cost for cleaning the river banks of creosote contaminated trash, debris, and soil was \$6.04/lineal meter (\$1.84/linear foot). Removal, treatment and disposal of contaminated muds cost approximately \$100.79/lineal meter (\$30.80/linear foot) of river bottom, exclusive of equipment purchase.

4. Quick response to spills of hazardous materials is of the utmost importance in reducing dispersion of the material and, ultimately, in minimizing the cost of cleanup.

SECTION 3

RECOMMENDATIONS

1. Additional testing should be conducted to determine the levels at which creosote is dangerous to humans, particularly in light of the hypersensitivity exhibited by some workers.

2. Methods for locating and quantifying contamination of river beds need to be improved.

3. The cleanup of the remaining reaches of the Little Menomonee should be completed as soon as funds become available--perhaps by diverting the river and using land vehicles.

4. A small dredge such as those used on the Little Menomonee may be suitable where the pollutant is not interspersed with the bottom muds. Otherwise, damming or diversion of the river, coupled with mechanical removal using front loaders or bulldozers, would be preferred.

SECTION 4

TOXICITY STUDIES AND ANALYTICAL PROCEDURES

Before initiation of cleanup activities, it was necessary to establish the level of creosote-contaminated mud that was toxic to aquatic plants and animals as well as the level at which creosote became an irritant to humans. In addition, a rapid field procedure was necessary to permit determination of creosote concentrations immediately after cleaning to enable recleaning if tests indicated that the toxicity level was exceeded. A discussion of these results and procedures follows.

TOXICITY STUDIES

Creosote is a relatively stable substance composed of liquid and solid aromatic hydrocarbons, tar acids (up to 8%) and tar bases. It is heavier than water and practically insoluble. In the Little Menomonee River, the alleged discharge of creosote occurred over a number of years and tended to distribute unevenly throughout the mud layer at depths up to 0.6-1.0 m (2 to 3.5 ft.). Because of its aromatic and volatile nature, it was not possible to identify the contaminant specifically as creosote since some of the lighter fractions had been stripped off. The basic nature of the material, however, left little doubt that it was of coal tar origin.

Two types of bioassays were used to determine tolerance limits--static and continuous. The static bioassay is suitable to detect and evaluate toxicity that is not associated with excessive oxygen demand. The physical and chemical properties of the contaminant indicated that the static procedure as described in Standard Methods of the Examination of Water and Wastewater, 13th Edition, 1971, would be a suitable bioassay procedure. For these studies the test was modified as suggested by the addition of air to maintain higher levels of dissolved oxygen required by the test organisms.

Selection and Preparation of Test Materials and Organisms

Approximately 75.7 L (20 gal) of contaminated river mud from the Little Menomonee River was collected and returned to the laboratory for analysis and bioassay tests. Uncontaminated mud was selected from the river from a point upstream of the contaminant source. The uncontaminated mud contained 27 mg/L of hexane extractable material while the contaminated mud contained 15,150 mg/L of hexane extractable materials. Both values represent the arithmetic mean of five individual analyses.

Since creosote is only very slightly soluble in water it was decided to use City of Milwaukee tap water as the water source for the bioassay tests. Sediment transfer studies conducted in conjunction with the toxicity tests indicated only 1 mg/L of creosote in the water after a 5 day period. The sediment transfer study was conducted by placing approximately 2.5 L of contaminated mud in an 18.9 L (5 gal) aquarium and covering it with fresh tap water which had been run through activated carbon for removal of chlorine. The mud was allowed to settle and a 500 ml sample of the cover water was collected daily and analyzed by hexane extraction for the creosote concentration. These concentrations ranged from 0 to 1 mg/L.

Very little was known of the natural aquatic fauna of the Little Menomonee River at the advent of these tests. Observations led to the selection of Procambarus sp. (crayfish) as one of the test organisms. The remaining organisms selected had originally consisted of Lepomis macrochirus Raf. (bluegill), Semotilus atromaculatus (Mitchill) (creek chub) and Daphnia pulex (de Geer) (water flea). These selections were made based upon common occurrence in southeastern Wisconsin waters. Later it was discovered that Rhinichthys atratulus (Hermann) (short nosed dace) had been collected in the upper reach of the Little Menomonee River. Collected specimens were substituted for the Semotilus atromaculatus. The bluegills were obtained from a commercial breeder and ranged in size from 7.62 to 12.7 cm (3 to 5 in.) in length. The creek chub, crayfish and daphnia were purchased locally. The minnows were from 2.54 to 38 cm (1 to 15 in.), the crayfish approximately 7.62 cm (3 in.) and daphnia, 1.5 to 2.5 mm (0.05 to 0.09 in.) long. Once organisms were moved to controlled stock tanks prior to testing, the feeding was terminated until the completion of the test.

Seven 75.7-L (20-gal) and seven 18.9-L (5-gal) all glass aquariums were obtained for test purposes. A 1136-L (300-gal) steel water trough was obtained as a common holding tank. The holding tank was kept as near as possible to the test conditions of dissolved oxygen and temperature. All the specimens except the D. pulex (de Geer) were initially placed in the holding tank. The D. pulex (de Geer) were held in a 18.9-L (5-gal) aquarium. Two days before any test, the organisms to be used were moved into controlled stock tanks, either 75.7-L (20-gal) or 18.9-L (5-gal) aquariums for acclimation to test conditions. These tests were always an exact duplication of test conditions minus only the suspected toxic materials.

Test Preparations

Four 75.7-L (20-gal) and four 18.9-L (5-gal) aquariums were set aside as test containers. One of each type received 2 liters of the concentrated creosote contaminated (15,150 mg/L) mud. The remaining pairs received 2 liters of 8240-, 1730-, and 205-mg/L creosote-contaminated muds. All the tanks were then filled with tapwater filtered through activated charcoal to remove residual chlorine. These served as test tanks. The control and stock tanks were filled with filtered tapwater only. A 24-hour sedimentation time was allowed in the test containers before starting any test.

The test containers were placed in a 232.25-m² (2,500-ft²) laboratory. In-tank heaters and room air conditioners furnished temperature control. Dissolved oxygen levels were maintained with stone diffusers and aquarium pumps. Temperature was monitored continuously using an Auto Lite Model 1000 recording thermometer. Dissolved oxygen was monitored with a YSI dissolved oxygen meter and pH with a Beckman Model SS-2 pH meter.

Two series of tests were planned for each organism. The first series was used to test various levels of contamination pinpointing the toxic range. The second was to concentrate in that range to more clearly define the toxic concentration. Time remaining, special tests applying additional external stress of pH and temperature were to be conducted.

Series One Tests

The first toxicity series was arranged in two flights for convenience. Daphnia pulex (de Geer) and Rhinichthys atratulus (Mitchill) were tested in the first flight and Lepomis macrochirus Raf. and Procambrus sp were tested in the second. The controls for each flight were in separate aquariums containing only filtered tapwater. The results of the first toxicity series are shown on Tables 1 and 2.

The results of the initial tests series indicated creosote concentrations up to 15,150 mg/L were not toxic to the test organisms. Some symptoms of distress did appear at the 15,150 mg/L level.

No mortalities were noticed in tests run on the D. pulex (de Geer) population. The control organisms were observed to rest on the bottom of the test container periodically. Such was not the case with those containers coated with creosote contaminated mud.

The Rhinichthys atratulus (Hermann) exhibited the poorest survival rate of the organisms tested in the first series. Those fish that died in the test tank were infected with fungus suggesting death in that manner. An examination of the gills and stomachs of the dead minnows in the test tanks provided slight additional information. Appearance of blood near the surface of the juncture of the fins to the body was noted in the tanks which used river mud, as is, and in the tanks that used river mud diluted by 50%.

The bluegill (Lepomus macrochirus Raf.) exhibited no lethality. Some reaction symptoms did appear in the concentrated tanks. The pelvic girdles and bases of the anal and dorsal fins appeared to have blood accumulating in the body juncture tissues. In addition, the fish seemed very dry and an apparent breakdown of the body mucus on some specimens was indicated by comparison to control specimens. Placing a single specimen back in control conditions resulted in a regeneration of mucus and a lightening of the tissue coloration of tissue adjoining the funds.

The Procambrus sp (crayfish) exhibited complete survival in the first series. Coloration changes similar to the bluegills were apparent in the joints of the appendages with the main pincer points being the most noticeable.

Table 1. TOXICITY TEST, SERIES ONE, FLIGHT ONE

Test organism and parameter measured	Control	Creosote (15,150 mg/l)	Creosote (8236 mg/l)	Creosote (1734 mg/l)	Creosote (205 mg/l)
<u>Daphnia pulex</u> (de Geer), 10 specimens					
Dissolved oxygen, mg/l	8.9	8.9	8.9	8.9	8.9
pH	7.0	7.0	7.0	7.0	7.0
Temperature, °C	21	21	21	21	21
96-hour survival ratio, %	100	100	100	100	100
<u>Rhinichthys atratulus</u> , 10 specimens					
Dissolved oxygen, mg/l	6.9	7.5	7.3	7.3	7.2
pH	7.0	7.0	7.0	7.0	7.0
Temperature, °C	19.5	19.5	19.5	19.5	19.5
96-hour survival ratio, %	80	70	70	80	80

Table 2. TOXICITY TEST, SERIES ONE, FLIGHT TWO

Test organism and parameter measured	Control	Creosote (15,150 mg/l)	Creosote (8236 mg/l)	Creosote (1734 mg/l)	Creosote (205 mg/l)
<u>Lepomis macrochirus</u> , 8 specimens					
Dissolved oxygen, mg/l	7.4	6.8	6.3	6.4	6.2
pH	7.0	7.0	7.0	7.0	7.0
Temperature, °C	20	20	20	20	20
96-hour survival ratio, %	100	88	88	88	100
<u>Procamburus sp</u>					
Dissolved oxygen	4.6	6.3	5.9	5.6	5.4
pH	7.0	7.0	7.0	7.0	7.0
Temperature, °C	22	22	22	22	22
96-hour survival ratio, %	100	100	100	100	100

All indications from the first series of tests demonstrated the non-lethality of the contaminant (creosote) at concentrations of 205 mg/L. Symptoms of distress appeared only in the highest concentration of creosote. The decision was made to place additional stress on the tested organisms.

Series Two Tests

Additional stress was placed upon the tested organisms by varying the pH temperature of the test containers. This selection was made based on the probability that stress might be applied as either the pH or the temperature in the river changed.

According to Bennett (3) fish are able to survive in water having a pH range from about 5 to 10. Neess (4) has indicated fish develop hypersensitivity to bacterial parasites in the range of pH 5.5. McCarraher (5) and others indicate survival was more successful at high pH than at low pH. The pH range selected for the tests, based upon the information presented, was 5-6.

Temperature influences the rate of metabolism in fish. It is often critical in spawning and embryo development and influences the relative activity of fish in water. In addition, increases in temperature can generally be linked with changes in chemical solubility. Bennett (3) sets the lethal temperature point for bluegills at 31.5°C after acclimatization at 20°C before 24 hours. The holding and stabilization tanks were set at 20°C before introduction of the organisms into the test range of 25°C to 30°C.

After the termination of the first series of tests, the aquaria were cleaned and rinsed with clear water. A control with only filtered tapwater was established, along with control tanks varying pH only and temperature only. The remaining four tanks received two liters each of the concentrated mud and a covering of filtered tapwater. Four were set in the selected temperature range (25°C to 30°C) and the remaining four in the selected pH range (pH 5 to 6). Twenty-four hours were allowed for sedimentation to occur.

The organisms tested in the stress series were Lepomis macrochirus Raf., Rhinichthys atratulus (Hermann) and Procambrus sp. The results of the tested organisms are summarized in Table 3. Only the Rhinichthys atratulus (Hermann) exhibited a death rate of 71% and 57% within 96 hours in the stress and creosote tanks, respectively. Survival of the remaining organisms tested coincided with the initial unstressed survey.

The apparent toxic response of the dace population to the creosote plus stress condition is in fact quite deceptive in nature.

The reaction symptoms exhibited by the bluegills and crayfish in the initial study were even more pronounced under stress conditions. Additional lesions were apparent on the sides of the bluegills and fungal infection was apparent.

Table 3. TOXICITY TEST SERIES TWO, SPECIAL STRESS

Test species and parameter measured	Control	Control & pH	Control & temp.	Creosote & pH	Creosote & temp. ¹
<u>Rhinichthys atratulus</u> , 10 specimens					
Dissolved oxygen, mg/l	6.6	6.3	5.6	5.9	5.4
pH	7.0	5.9	7.0	5.8	7.0
Temperature, °C	22	22	26	22	26
96-hour survival ratio, %	100	100	90	29	43
<u>Lepomis macrochirus</u> , 10 specimens					
Dissolved oxygen, mg/l	7.3	6.3	5.6	5.2	4.0
pH	7.0	5.9	7.0	5.7	7.0
Temperature, °C	21	21	26	22	28
96-hour survival ratio, %	100	90	100	100	100
<u>Procambrus</u> sp., 10 specimens					
Dissolved oxygen, mg/l	6.3	6.1	5.8	5.2	4.8
pH	7.0	5.8	7.0	5.8	7.0
Temperature, °C	21	22	25	22	26
96-hour survival ratio, %	100	100	100	100	100

1. Creosote contaminated muds containing 15,150 mg/l were used in all tests with special stress.

The dace remaining alive after 96 hours were all infected with a fungus growth, and all dead dace were covered with fungal suggesting the possibility of death by disease other than creosote toxicity.

The accumulated data clearly indicates an apparent reaction of the test organisms to creosote contamination. The mucus breakdown on the bluegills and dace, the blood red areas apparent on the crayfish as well as the fish, the appearance of lesions and finally fungal infection of the fish, suggest a reaction quite similar to the human response. Creosote appears to be, at least in concentrations in the area of 15,000 mg/l or more, an irritant. Although not toxic in itself, in combination with additional external stress or in sufficient concentration and detention by itself, creosote apparently renders the organism much more susceptible to disease. Creosote levels in the range of 7,500 mg/l elicit this response only slightly and levels in the range of 1500 mg/l apparently exhibit no ill effects.

Skin Irritation Studies

The contamination of the Little Menomonee River was brought to the attention of the general public in 1971 when high school students involved in a cleanup of the river received rather severe chemical burns. A search of the literature failed to turn up any information on the skin toxicity levels of creosote in humans. Although toxicological studies were beyond the scope of this project, it was necessary to establish guidelines for residual creosote concentrations which were not harmful to humans who might come in contact with the river muds.

Two series of tests were conducted to evaluate the skin irritation potential of the creosote/bottom mud mixture. The first series contained various creosote concentrations up to 15,150 mg/l creosote. The second series contained samples of 5%, 10% and 20% creosote/mud mixture as well as a creosote/water emulsion.

The skin irritation tests were performed by the Rossner-Hixson Laboratories in Chicago, Illinois, with samples supplied by Envirex personnel. The procedure used in testing was as follows.

The hair was clipped from the abdomen of six male albino rabbits for each sample and two areas of the abdomen approximately ten centimeters apart were designated for application of the patches. A one inch square site on the right side was abraded while a similar area on the left remained unabraded.

In each group of six rabbits, 0.5 ml of sample was placed on the skin at each abraded and intact site under a small square of cotton gauze and maintained in contact with the skin under a larger square of polyethylene film and anchored to the skin with strips of adhesive tape. A square of flannel cloth was then taped around the trunk of the animal to further protect the patches from being dislodged.

After 24 hours, the vest and patches were removed, and the skin was examined for signs of irritation (erythema and/or edema). Examination was made again after 72 hours.

Skin irritation scores are presented in Table 4. A guide to evaluation and scoring of skin irritation reactions is given in Table 5.

The primary irritation scores of 0.16 to 0.58 indicated that none of the samples are skin irritants. In accordance with Federal hazardous Substances Labeling Act Regulations (F.R. 119), a primary irritation score of 5 is required for designation as a primary skin irritant in the experimental procedure. Therefore, creosote concentrations in these muds up to 10,000 ppm would not be considered as potential skin irritants for humans.

Immediately following the completion of these tests, several of the crew members who were working on the cleanup contacted the creosote-oil contaminant and experienced painful "chemical burns". Medical advice and attention was pursued for two crew members exhibiting a possible hypersensitivity. No medicine of any sort was prescribed; however, they were directed to avoid further contact with the material and to keep the burns clean. It was the doctor's opinion that certain skin types may be more susceptible to adverse reactions.

Following these burns, Rossner-Hixson Laboratories was asked to repeat the tests with new mud samples containing creosote/mud mixtures of 5, 10 and 20% creosote. A fourth sample containing an oil/water scum that separates from creosote under quiescent conditions was also tested.

Sensitivity tests identical to the first series were conducted and the results are shown in Table 6. The primary irritation scores of 0.25 to 0.84 for the 5% to 20% creosote/mud mixture indicated that these samples were not skin irritants. The primary irritation score for the creosote/water emulsion was 4.58 indicating the likelihood that the creosote/water emulsion may be a primary irritant.

These tests should not be considered as conclusive evidence that the creosote/mud is not a primary skin irritant because even though laboratory tests indicated that it was not, crew members did in fact suffer chemical burns. In addition, there is evidence that creosote can be transferred through the skin, causing damage to certain internal organs.

It is recommended that additional testing be conducted to establish the levels at which contact with creosote becomes hazardous to human health.

Standard of Performance

Based on the results of the toxicity study, the following standards of performance were established:

1. To protect incumbent and potential aquatic fauna, the maximum residual creosote which may remain in the muds after cleanup should not exceed 5,000 ppm (1/2%).

Table 4. RABBIT PRIMARY SKIN IRRITATION TESTS: SERIES I

Rabbit No.	24 Hours				72 Hours			
	Unabraded		Abraded		Unabraded		Abraded	
	Erythema	Edema	Erythema	Edema	Erythema	Edema	Erythema	Edema
Sample: Mud Sample 6/4/73, #1, 10,000 ppm Creosote								
1926	1	0	1	0	0	0	0	0
1927	1	1	1	1	0	0	0	0
1928	1	0	1	0	0	0	0	0
1929	1	0	1	0	0	0	0	0
1930	0	0	0	0	0	0	0	0
1931	1	0	1	0	0	0	0	0
Average	0.83	0.17	0.83	0.17	0	0	0	0
Primary irritation score:					0.5			

Sample: Mud Sample 6/4/73, #2, 5000 ppm Creosote

1932	1	0	1	0	0	0	0	0
1933	0	0	0	0	0	0	0	0
1934	1	0	1	1	0	0	0	0
1935	1	0	1	2	0	0	0	0
1936	0	0	0	0	0	0	0	0
1937	1	0	1	1	0	0	0	0
Average	0.83	0	0.83	0.67	0	0	0	0
Primary irritation score:					0.58			

(Continued)

Table 4 (Continued).

Rabbit No.	24 Hours				72 Hours			
	Unabraded		Abraded		Unabraded		Abraded	
	Erythema	Edema	Erythema	Edema	Erythema	Edema	Erythema	Edema
Sample: Mud Sample 6/4/73, 1000 ppm Creosote								
1938	1	0	1	1	0	0	0	0
1939	1	0	1	1	0	0	0	0
1940	0	0	0	0	0	0	0	0
1941	0	0	0	0	0	0	0	0
1942	0	0	0	0	0	0	0	0
1943	0	0	0	0	0	0	0	0
Average	0.33	0	0.33	0.33	0	0	0	0
Primary irritation score: 0.25								

Sample: Mud Sample 6/4/73, 100 ppm Creosote

1944	0	0	0	0	0	0	0	0
1945	1	0	1	0	0	0	0	0
1946	0	1	0	1	0	0	0	0
1947	0	0	0	0	0	0	0	0
1948	1	0	1	0	0	0	0	0
1949	0	0	0	0	0	0	0	0
Average	0.33	0.17	0.33	0.17	0	0	0	0
Primary irritation score: 0.25								

(Continued)

Table 4 (Continued).

Rabbit No.	24 Hours				72 Hours			
	Unabraded		Abraded		Unabraded		Abraded	
	Erythema	Edema	Erythema	Edema	Erythema	Edema	Erythema	Edema
	Sample: Mud Sample 6/4/73, Control							
1963	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0
1966	1	0	1	0	0	0	0	0
1967	0	0	0	0	0	0	0	0
1968	1	0	1	0	0	0	0	0
Average	0.33	0	0.33	0	0	0	0	0

Primary irritation score: 0.16

Table 5. EVALUATION FACTORS
FOR PRIMARY SKIN IRRITATION TEST*

Symptom	Value*
A. Erythema and eschar formation	
Very slight erythema (barely perceptible)	1
Well defined erythema	2
Moderate to severe erythema	3
Severe erythema (beet redness) to slight eschar formation (injuries in depth)	4
B. Edema formation	
Very slight edema (barely perceptible)	1
Slight edema (edges of area well defined by definite raising)	2
Moderate edema (area raised approximately 1 mm)	3
Severe edema (raised more than 1 mm and extending beyond area of exposure)	4

* The value recorded for each reading is the average value of the animals subject to the test.

* Calculation of primary scores is done as follows:

Average values for erythema and eschar formation at 24 hours and 72 hours for intact are added to values on abraded skin at 24 hours and 72 hours (four values). Similarly, values for edema formation at 24 hours and 72 hours for intact and abraded skin are added (four values).

The total of the eight values is divided by 4 to give the primary irritation score.

A primary skin irritant is a substance that results in an empirical primary irritation score of 5 or more.

2. To establish 24-hour residence zones of passage for incumbent or potential aquatic fauna the maximum residual creosote which may remain in the muds after cleanup should not exceed 10,000 ppm (1%).
3. To prevent potential hazard to humans, scum or potential scum-generating areas should not exceed residual concentrations of 10,000 ppm (1%) of creosote in the mud after cleanup.

Sufficient contaminant muds were removed to achieve objective 1, the protection of incumbent and potential aquatic fauna.

FIELD PROCEDURE - HEXANE EXTRACTABLES

A rapid field procedure for estimating the creosote concentration in the bottom muds was also developed. The method utilized color standards of hexane (petroleum ether) extractions concentrated from an actual Little Menomonee mud/oil analysis (using the soxhlet extraction technique). These color standards for oil concentration were then compared with decanted and filtered petroleum ether extract taken from on-site bottom mud oil analyses.

The field technique was rapid, requiring approximately one hour from start to finish. Bottom-mud oil analyses using the soxhlet technique were compared with the field method, with errors consistently on the conservative side (field procedure estimates were high because of background color). The detailed procedure is given in Table 7.

Table 6. RABBIT PRIMARY SKIN IRRITATION TESTS: SERIES II

Rabbit No.	24 Hours				72 Hours			
	Unabraded		Abraded		Unabraded		Abraded	
	Erythema	Edema	Erythema	Edema	Erythema	Edema	Erythema	Edema
Sample: 5% Creosote/Mud								
2102	1	0	1	0	0	0	0	0
2102	1	0	1	0	0	0	0	0
2103	0	0	0	0	0	0	0	0
2104	0	0	0	0	0	0	0	0
2105	1	0	1	0	0	0	0	0
2106	0	0	0	0	0	0	0	0
Average	0.5	0	0.5	0	0	0	0	0
Primary irritation score: 0.25								
Sample: 10% Creosote/Mud								
2107	0	0	0	0	0	0	0	0
2108	1	0	1	0	0	0	0	0
2109	0	0	0	0	0	0	0	0
2110	1	0	1	0	0	0	0	0
2111	0	0	0	0	0	0	0	0
2112	1	0	1	0	0	0	0	0
Average	0.5	0	0.5	0	0	0	0	0
Primary irritation score: 0.25								
Sample: 20% Creosote/Mud								
2113	1	0	1	0	0	0	0	0
2114	1	0	1	0	0	0	0	0
2115	1	0	1	0	1	0	1	0
2116	1	0	1	0	0	0	0	0
2117	1	0	1	0	1	0	1	0
2118	1	1	1	1	1	0	1	0
Average	1.0	0.17	1.0	0.17	0.5	0	0.5	0
Primary irritation score: 0.84								
Sample: Creosote/Mud Emulsion								
2119	2	1	2	1	3	1	3	1
2120	2	2	2	2	4	1	4	1
2121	2	4	2	4	4	1	4	1
2122	2	2	2	2	3	1	3	1
2123	2	3	2	3	4	1	4	1
2124	2	3	2	3	4	1	4	1
Average	2.0	2.5	2.0	2.5	3.67	1.0	3.67	1.0
Primary irritation score: 4.58								

Table 7. FIELD ANALYTICAL METHOD
FOR ESTIMATED HEXANE EXTRACTABLE SUBSTANCE IN MUD

Item	Procedure
1. <u>Apparatus</u>	Burrell shaker - trip balance 12 - 250 erlenmeyer flasks Saran wrap Sample bottles Spatula #40 filter paper Small funnell Screw tap test tubes 1 ml graduated pipet Cenco moisture meter
2. <u>Reagents</u>	Distilled water Solvent (petroleum ether) Hydrochloric acid
3. <u>Procedure</u>	Weigh about 5 grams of well mixed mud into an erlenmeyer flask (avoid large stones, twigs, leaves, etc.). Add 45 ml distilled water, 0.5 ml HCL, and 50 ml solvent, mix so all mud is in solution, cover with saran wrap and secure with rubber band. Place on Burrell shaker and shake for 1 hour at a setting as high as possible (4) without spilling or getting solvent trapped around the top of flask. Remove and filter solvent layer (top) through #40 filter paper into small screw tap test tubes and compare with standards. Estimate as best as possible to nearest 100 or 200 mg/L. (Run 3 or 4 samples and average.) Also run a solids content on Cenco moisture balance.
4. <u>Calculations</u>	$\% \text{ solids} = 100 - \text{reading of Cenco meter}$ $\text{Weight dry sample} = \text{wet sample weight} \times \frac{\% \text{ solids}}{100}$ $\text{Estimated extractable material (in mg/kg dry mud)} = \frac{50 \times \text{est. standard reading}}{\text{dry weight sample}}$ $\text{Estimated extractable material (in mg/kg wet mud)} = \frac{50 \times \text{ext. standard reading}}{\text{Wet weight sample}}$

SECTION 5

CLEANUP AND TREATMENT METHODS

The removal of hazardous pollutants from watercourses is a relatively new area of activity and presented numerous challenges during the duration of the cleanup. The Little Menomonee River is narrow and meanders significantly in the 5 miles of contaminated reach (Figure 1). The river is located in a low population density area and in many places is up to 0.5 mile from an access road. The stream is shallow and is not navigable except by flat bottom rowboats. Its soft, marshy banks precluded the use of motor powered vehicles for removal of debris and contaminated vegetation. Because the discharge of creosote occurred over many years it was distributed in layers in the stream bottom and in the river bank at points where the stream changed direction or widened.

BANKLINE CLEANING

The first phase of the cleanup operation involved the removal of debris, overhanging tree limbs and creosote saturated vegetation as well as bottom muds which were exposed during the flow and creosote contaminated bank material. As with all too many streams in this country, man's lack of concern for the environment resulted in the disposal of much trash into this already abused stream. Debris removed included refrigerators, stoves, old tires, an engine block, bed springs, bottles, cans and other materials too numerous to mention. Debris was manually loaded in flat bottomed boats and hauled to the nearest access point where it was deposited into dumpsters for disposal in a landfill.

All dead tree limbs and branches which interfered with the bottom cleanup machinery were cut up and removed. In some cases live tree branches which overhung the river bank had to be cut and hauled away. Because of the inaccessibility of the river, this effort required a significant amount of manual labor. Some reduction in labor was effected by using 2 portable leaf and limb shredders. Uncontaminated vegetation was mulched and spread as ground cover.

Some bank areas which contained visible amounts of creosote were cleaned by rototilling the earth, shoveling the contaminated soil into boats and hauling it away. The stripped areas were then seeded with a quick germinating grass seed to prevent erosion.

In some areas contaminated bottom muds were exposed during low flow periods leaving an island of creosote laden mud. These areas were cleaned by shoveling the mud into boats and hauling to dumpsters for landfill disposal.

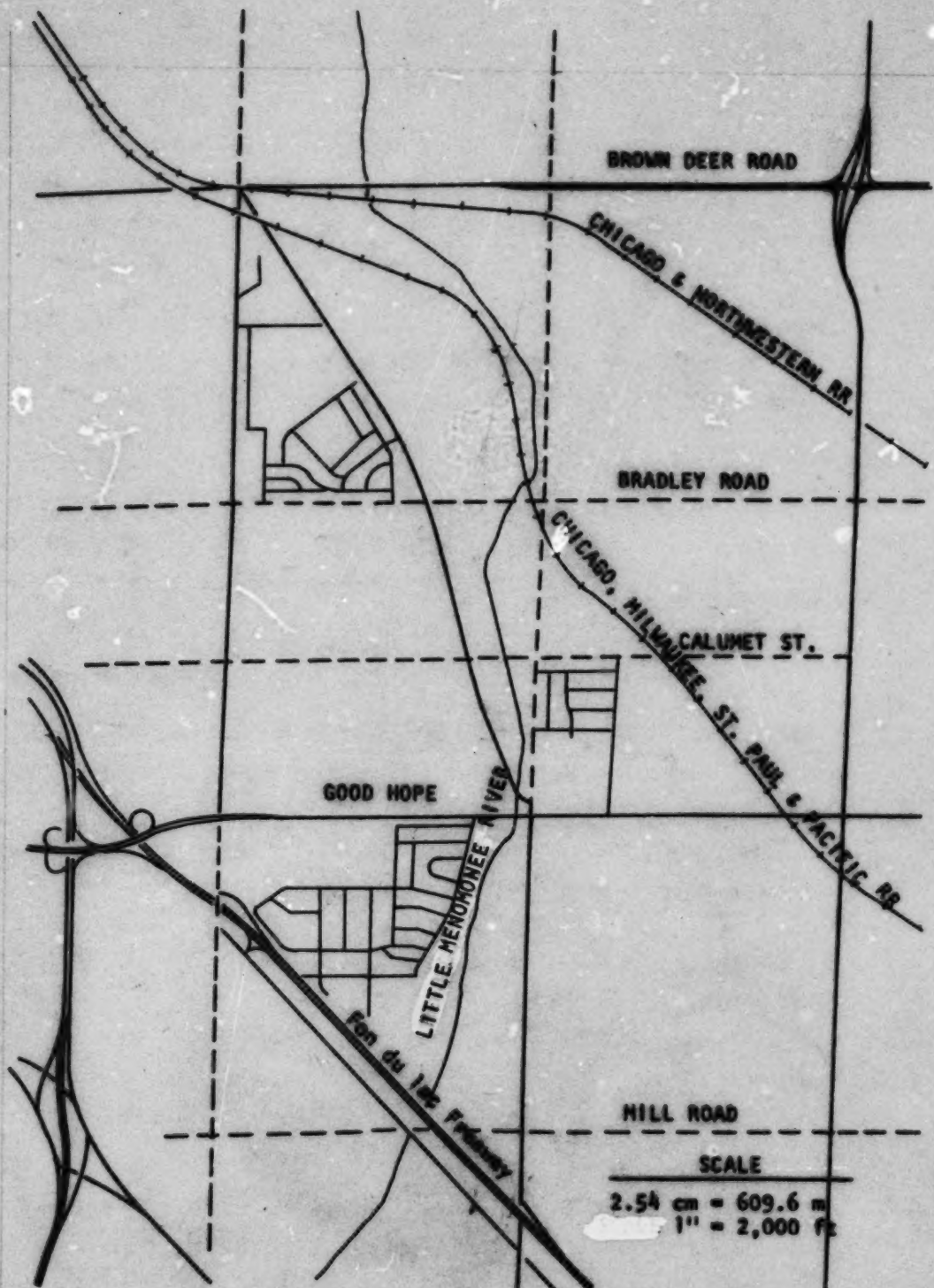


Figure 1. Project location map

RIVER BOTTOM CLEANING

Two river sweepers were utilized to remove muds from the river bottom. The first (Sweeper I) shown in Figure 2 was a floating, pontoon supported chassis, containing a suction line (mast) which was hydraulically powered to move simultaneously in three dimensions, along with an operator's chair and control instruments. The suction line consisted of a 7.6 cm (3 in.) thin walled steel tubing with a 40.6 cm (16 in.) diameter circular spun-aluminum suction head attached to the bottom end. The suction line, which terminated at the top of the mast, was connected to a 7.6 cm (3 in.) flexible rubber hose which lead to a suction pump located on shore. The suction head could be extended 1.4 m (4.5 ft) below the water surface, and provisions were made to allow greater depths to be achieved by adding extensions in deeper water.

Based on the work done in Phase I a second sweeper (Sweeper II) was designed and fabricated incorporating the following improved features:

1. Independent frames bearing the hydraulic operating package and suction pump to minimize the difficult problem of movement over rough terrain and reduce the headloss on the suction side of the pump.
2. A gimbal mounted suction mast extended over the support frame to permit a continuous sweep rather than a "post-hole" type movement. In addition, this design offered a greater fixed point reach and much better access to the edges of the stream.
3. Hydraulic control of the boom and support studs from a central operator's platform.
4. Downstream movement of the sweeper by means of a winch for more accurate placement of the sweeper.

The second river sweeper assembly had a pontoon supported aluminum chassis with overall dimensions of 2.7 x 7.9 m (9x26 ft) including a front outrigger which contained two hydraulic spuds for holding the sweeper stationary in the stream. With the sweeper extension attached (for deeper water), the overall length was 9.58 m (31.5 ft).

The sweeper consisted of a suction arm with attached suction head capable of removing stream bottom mud and sediment by a vacuuming action. The suction head was equipped with two hydraulically operated cutting knives to prevent debris from clogging the head and to aid in removing mud too stable for vacuum retrieval alone.

The suction arm was capable of sweeping both laterally and vertically. This movement was accomplished through the use of two hydraulic cylinders, operated from a single control lever located on the main platform in the operator instrumentation area of the sweeper. This arrangement permitted the operator to move the boom while maintaining a "feel" of the river bottom.



SUCTION LINE

SPUDS

SUCTION HEAD

Figure 2. River sweeper I

Once a section of stream bottom was swept, the entire sweeper was moved by raising the hydraulic spuds, activating a winch located on the rear of the sweeper, and resetting the spuds in the stream bottom.

A gasoline engine driven suction pump was located on the sweeper to provide the "vacuum" and a gasoline engine driven hydraulic pump supplied the hydraulic power for sweeper operation. A gasoline tank located on the rear of the sweeper aided in making the unit self-contained with a minimum of shoreside support equipment. Valving was provided to permit reversing the water flow to flush out the sweeper boom and head in case in clogging.

A general arrangement drawing of Sweeper II is given in Figure 3. An actual photograph of Sweeper II is shown in Figure 4.

Mud was pumped from the river bottom by means of two HYDR-O-MATIC 10.2 cm (4 in.) centrifugal trash pumps manufactured by the Hydromatic Pump Company of Haynesville, Ohio. Each of these self-priming pumps, Model No. 4OEP-VH4DWA, was wheel mounted and powered by a 30-horsepower, gasoline fuel engine. The pumps had a total head of 44 m (145 ft) at 6.3 l/s (100 gpm), a suction lift of 7.6 m (25 ft) and the ability to pass a 7.6 cm (3 in.) solids. A photograph of one of the land-based sweeper pumps is shown in Figure 5.

Hosing of 7.6 cm (3 in.) was used to connect the river sweeper suction line to the pump and also to connect the pump to the treatment process. Hard wall rubber hose was used on the suction side of the pump and one 15.2 m (50 ft) length on the discharge side, the remainder being common 7.6 cm (3 in.) mil hose or plastic hose. All hose connections were of the quick disconnect type to facilitate adding or removing hose sections as needed.

To prevent pluggages of the suction line between the sweeper head and the pump, a cleanout package was added to facilitate flushing of the suction header. This package included four 7.6 cm (3 in.) valves mounted on a rubber-tired wagon to permit the pumpage of clean river water back through the pump suction line. With this technique, most blockages could be removed in 1 to 3 minutes.

The pump discharge hose to the treatment system was kept as short as possible but extended approximately 395 m (1300 ft) on at least one occasion.

TREATMENT PROCESS

Since the Phase 1 study had shown that it was impossible to remove more than about 50% of the creosote from the bottom muds by froth flotation, it was decided to simplify the treatment process by using a small presettling tank for gross solids removal rather than the "mobile beach cleaner" used in Phase 1.

The bottom muds were therefore pumped into a 2.1 m (7 ft) diameter, conical-bottomed clarifier. The purpose of this clarifier was to remove as much of the heavy sand and mud as possible prior to introduction into the

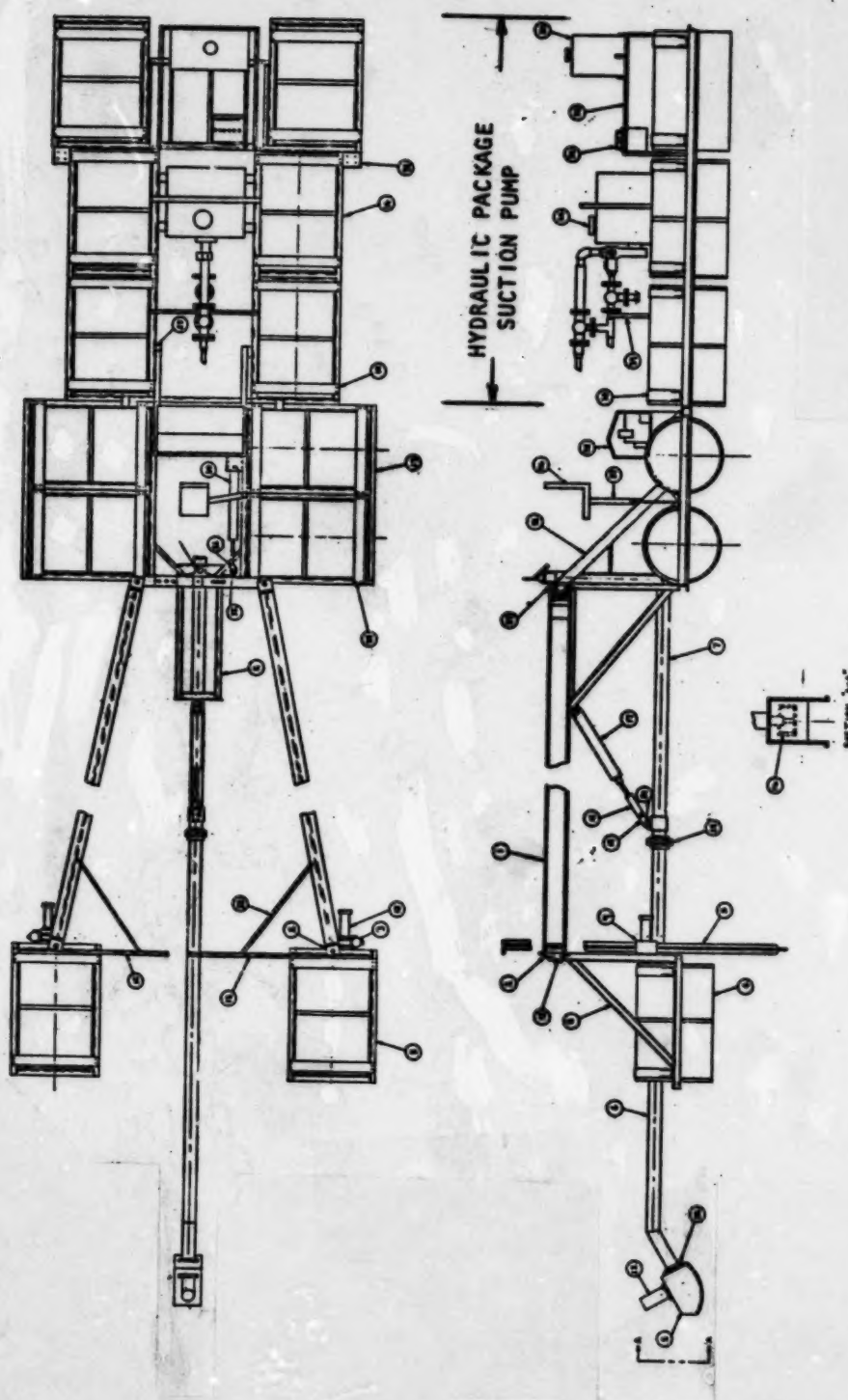


Figure 3. General arrangement drawing of river sweeper II



Figure 4. River Sweeper II



Figure 5. Land-based sweeper pump

reaction-clarifier section, since the removal of heavy sludge from the flat bottom mud flocculation-sedimentation tank was an extremely time consuming and tedious task.

Clarifier

The clarifier shown in Figure 6 was a center feed, peripheral weir type with a 3.9-m (13-ft) straight wall section. The 60-degree conical bottom was equipped with a 7.6-cm (3-in.) drawoff point valve for sludge removal. The entire clarifier was hinged and mounted on a small trailer for transfer to new setup points.

During initial operations, substantial difficulties were encountered with rocks and other debris clogging the sludge drawoff valve. This necessitated transfer of the clarifier contents and disassembly of the valve to remove the blockage.

Subsequently a manually cleaned bar screen was added to the clarifier inlet to remove large debris. This device consisted of a box 6.7 x 6.7 x 6.7 cm (2x2x2 ft) with a 0.63-cm (0.25-in.) bars spaced approximately 3.8 cm (1.5 in.) on center. Although this device required the full time attention of an operator, it reduced much of the down time which had occurred earlier in the project.

The sludge from this clarifier was generally on the order of a 6-10% solids and was pumped with a 7.6 cm (3 in.) gasoline driven HYDR-O-MATIC pump to a 18,925-L (5,000-gal) sludge holding tank.

Liquid Treatment System

The liquid treatment system used for this project was the hazardous spills vehicle developed by Envirex for the EPA under Contract 68-01-0099(6).

The spills vehicle is a completely operational, mobile physical-chemical treatment system with a hydraulic flow capacity of 12.6 L/s (200 gpm). The vehicle has its own self-contained power supply, a portable rubber reaction-settling tank, mixed media filters, carbon columns, chemical feed system and controls.

The clarifier liquid from the precleaning clarifier was conveyed by gravity to the reaction-sedimentation tank, shown in Figure 7, which consisted of a tank within a tank. The inner tank had a diameter of 3.43 m (11.25 ft) with nineteen 10.16-cm (40-in.) diameter orifices located around the periphery of the tank, 27.94-cm (11-in.) below the top. The outer tank was 7.6 m (25 ft) in diameter and 1.4 m (4.5 ft) high, as was the inner tank. The inner tank, which was used as a flocculation chamber in this process, had a volume of 12,718 L (3,360 gal). The outer tank was used as a sedimentation basin and had a volume of 49,886 L (13,180 gal), for total volume of both tanks of 62,604 L (16,540 gal).

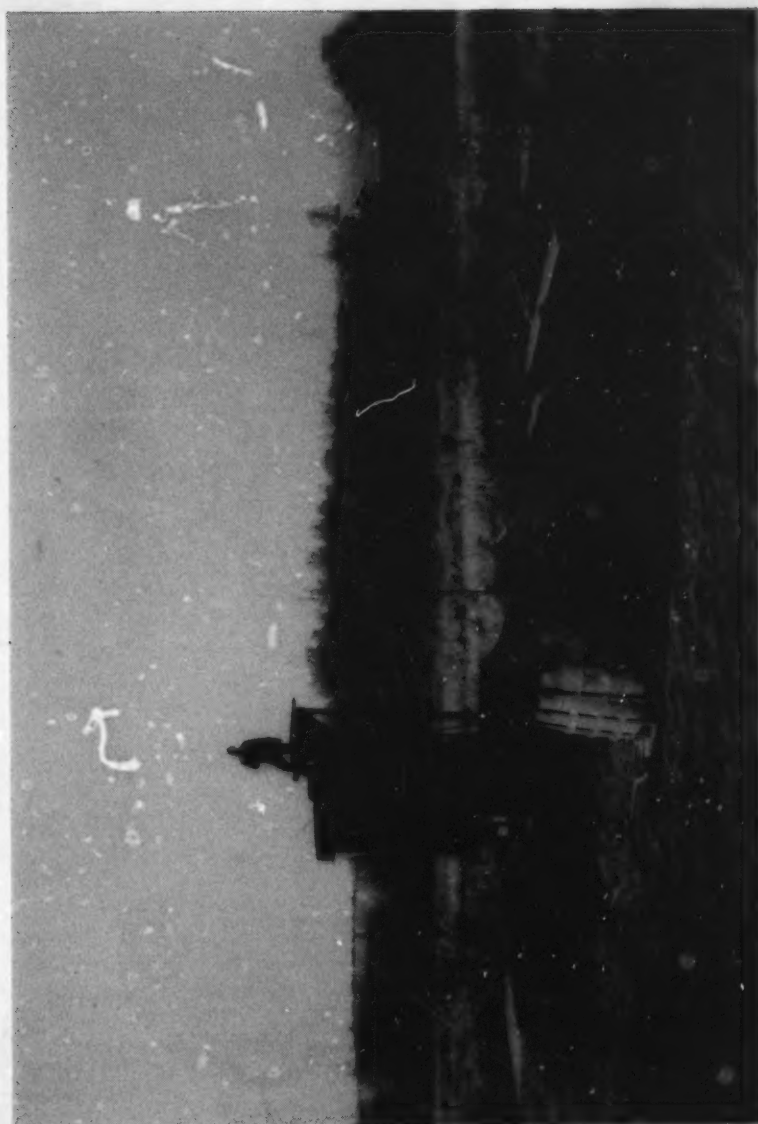


Figure 6. Clarifier (presettler tank)



Figure 7. Reaction-clarifier tank

Because of the frequent shutdowns to move Sweeper I and to remove hose blockages, the system was operated on a semicontinuous basis. Water was pumped from the reaction tank through an inline mixer installed on the spills vehicle (Figure 8) where 50 to 200 mg/l of FeCl_3 and 1 mg/l of Atlasep 105C were added for coagulation by means of a BIF, Model 1271-23-9121, chemical feed pump and the flow rate measured. The flow from this header was connected by hose to an opening on the bottom of the inner (flocculation) tank. By this means the flow continued in a closed loop until all the coagulant had been added. After this was completed, the liquid was allowed to settle before further introduction of the supernatant into the hazardous spills vehicle for mixed-media filtration and carbon adsorption.

The hazardous spills vehicle shown in Figure 8 was originally developed as a mobile unit which could quickly respond to the site of a spill of both organic and inorganic water soluble substances such as ammonia, phenol, chlorine and methyl alcohol, heavy metal compounds, and chlorinated hydrocarbon pesticides. The entire treatment system was mounted on a 13.7-x 2.5-m (45-x 8-ft) truck trailer. The portable sedimentation tank was stored on the trailer deck during transport and set up in the proximity of the vehicle at the site of the spill. The major components of this vehicle included the capability for addition of chemicals for coagulation and pH adjustment, followed by mixed media filtration and carbon adsorption. A block diagram of the process flow is shown in Figure 9.

The mixed media filtration process consisted of three pressure filtration columns, operated in parallel. The columns were each 106.68 cm (42 in.) in diameter and 203.2 cm (80 in.) high and contained 45.72 cm (18 in.) of sand beneath 60.96 cm (24 in.) of anthracite. The sand used was common red flint sand having an effective size of 0.5 mm and a uniformity coefficient of 1.5. The anthracite used was Anthrafilt No. 1 1/2, with a standard size of 0.85 and 0.95 mm. The total surface area of the three columns was 2.68 m^2 (28.8 ft^2). The columns housing the filter media were flakeglass lined steel pressure vessels.

Carbon adsorption was accomplished in three columns that could be operated either in parallel or series. These columns were 210.82 cm (83 in.) in diameter by 266.7 cm (105 in.) high and were enclosed in flakeglass lined steel pressure vessels. For use on this project, only one carbon column was filled with carbon and used. The column was filled with 6,000 lb of 18 x 40 mesh Witco Grade 718 activated carbon. The wetted volume of carbon was estimated to be 6.51 m^3 (230 ft^3).

Three portable rubber pillow tanks were also part of this vehicle. These tanks were 3.66 x 3.66 m (12 x 12 ft) and had a volume of 11,355 L (3000 gal). Their purpose was to store sludge from the sedimentation tank and hold a supply of backwash water for the mixed media and carbon columns. The system was designed to be backwashed with the wash water going back to the sedimentation tank, where the solids are settled out and handled with the normal sludge. In the application on the Little Menomonee River, one of

the pillow tanks was used to store carbon column effluent for backwash. The sludge from the sedimentation tank was pumped directly from the tank to a 18,925-L (5000-gal) sludge storage tank and then transported to a Wisconsin Department of Natural Resources approved landfill.



Figure 8. Hazardous spills vehicle

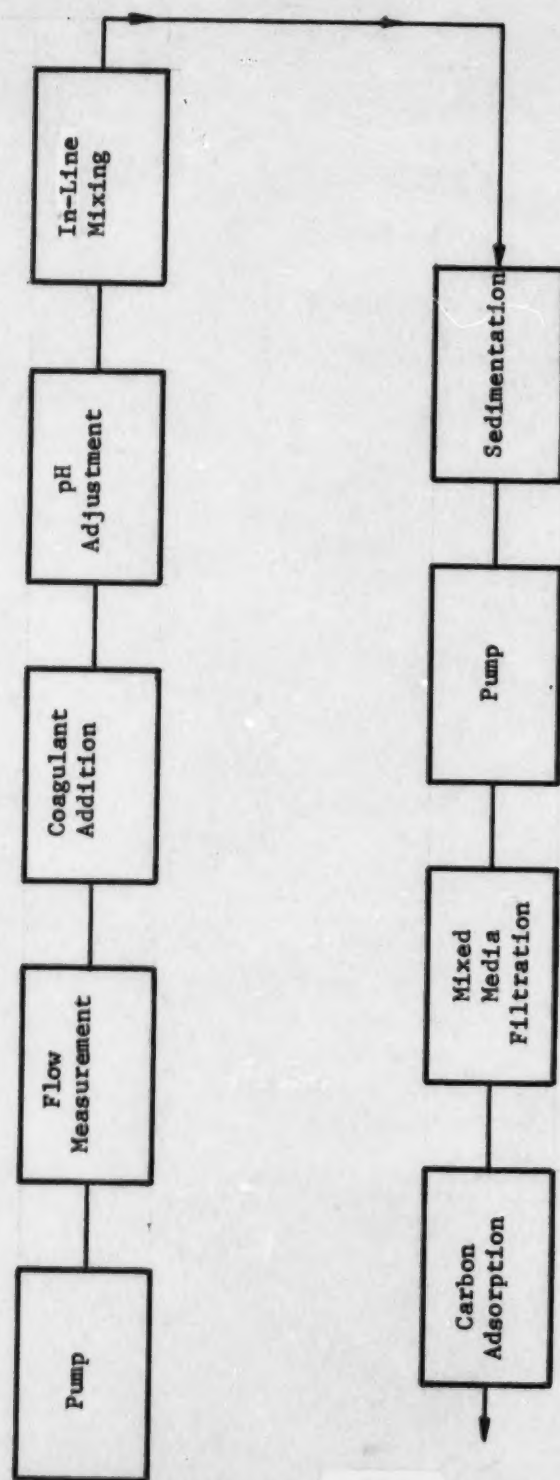


Figure 9. Block diagram showing process flow

SECTION 6

OPERATING RESULTS

The banks and bottom muds of the Little Menomonee River were contaminated with a creosote-type material from Brown Deer Road south to approximately Silver Spring Road (Figure 10). The degree of contamination varied widely throughout this stretch, with shallow areas of fast-moving water being devoid of contamination and some of the wide slow velocity areas having high concentrations. Areas of high contamination were found from the creosoting operation at the railroad trestle south of Brown Deer Road south to approximately Bradley Road and in the "oxbow" area where the river flows under the Fond du Lac Freeway.

The basic project philosophy was to begin cleaning at the upstream end and to work downstream, thereby preventing recontamination by the suspension of contaminants during high flow periods. The cleanup included two basic phases--bankline and bottom cleaning.

BANKLINE CLEANING

Bankline cleaning was the first field effort since it was necessary to remove all obstructions and debris prior to bottom cleaning. It also permitted the contractor to get a head start on the project while the treatment equipment was being prepared for deployment.

Bankline cleaning was initiated at the railroad trestle approximately 38 m (190 ft) south of Brown Deer Road and was terminated 4023 m (13,200 ft) downstream, somewhat upstream of the Fond du Lac Freeway. The amount of debris removed during the bankline cleaning was approximately 305 m³ (400 yd³). In addition an undetermined amount of brush was mulched on-site and left to decompose. The bankline cleaning effort required approximately 2800 man-hours of work.

Although there were relatively few areas of the river bank that required removal of contaminated soil, this was an extremely time consuming and expensive task. Whenever there were visual indications of creosote deposits on the banks the area was cored and soil removed until there was no visual evidence of contamination. The bank was then reseeded. Throughout the entire project, extreme caution was exerted to insure an absolute minimum of damage to the environment, which contributed to the extremely high cost of cleanup.

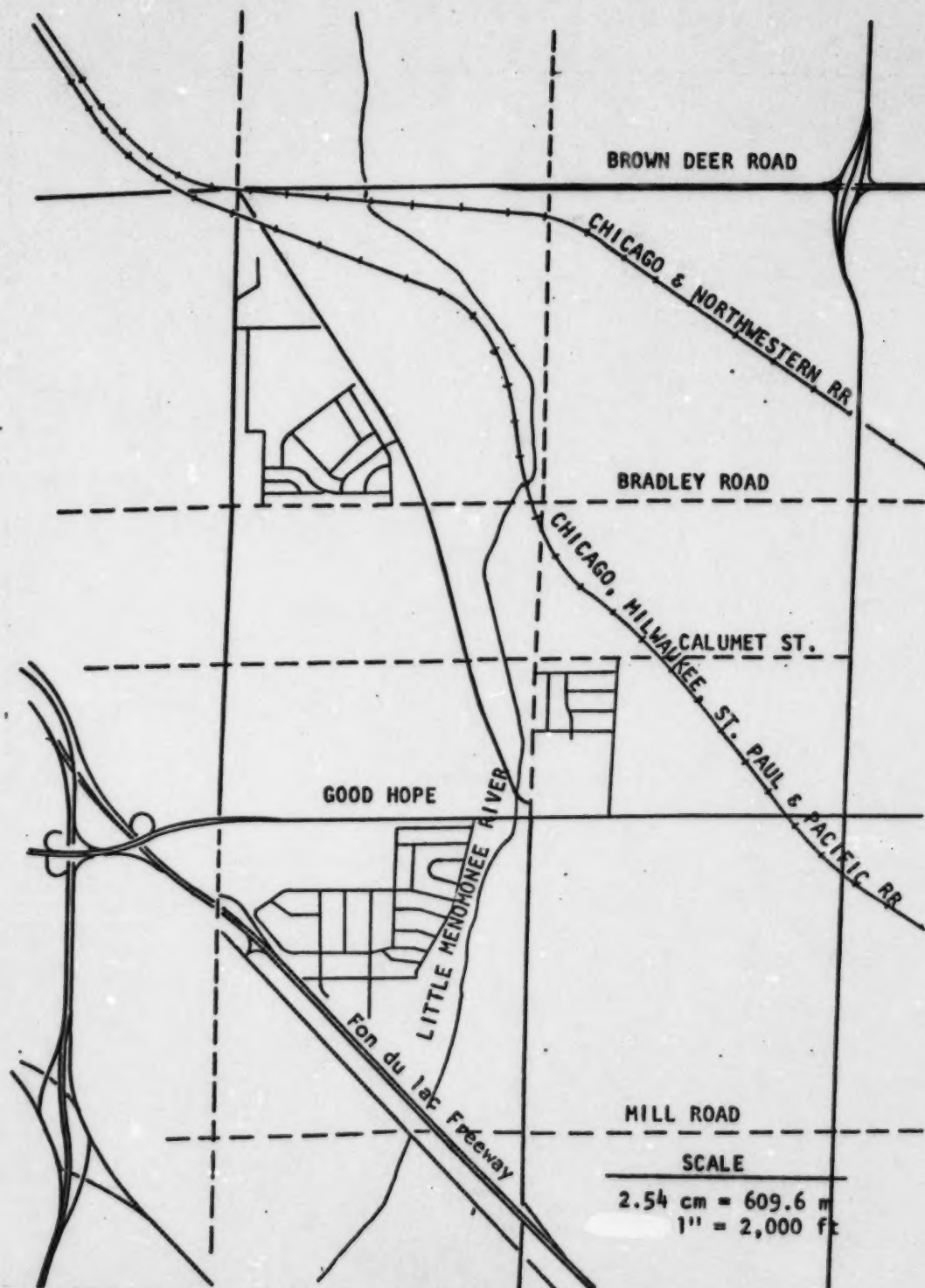


Figure 10. Map showing location of Little Menomonee River.

RIVER BOTTOM CLEANING

Removal of contaminated bottom muds was initiated 152.4 m (500 ft) downstream of Brown Deer Road. During the approximately 3.5 months of operation, 1231 linear meters (4040 linear feet) or approximately 9290 m² (100,000 ft²) of river bottom were cleaned.

Before the initiation of river bottom cleanup, a complete sampling survey was undertaken to identify the concentration of hexane-soluble materials in the bottom muds. Samples were collected by means of a Pfleger corer to a depth of 0.6 m (2 ft). Three cores were taken at each cross-section, with the interval between sampling stations ranging from approximately 7.6 to 38.1 m (25 to 125 ft), depending on the conditions found at each site. The cores were then composited and the hexane-solubles were determined by the field procedure described in Section 5. A summary of these results is shown in Table 8.

The results of this pre-cleanup survey were used as a primary measure of the degree of contamination. In most cases a secondary qualitative measure of contamination could be obtained by the amount of oil rising to the surface as the crew worked in the river.

Because of the length of river that was cleaned, the treatment system was set up in three different locations. Movement of equipment from one location to another required approximately 14 man-days of effort including the time required to remove sludge from the reaction-settling tanks.

A typical setup of the entire retrieval-treatment system is given in Figure 11. Mud was pumped from the river via a 7.6 cm (3 in.) hose to the presettling tank. The clarifier wastewater then flowed by gravity to the reaction tank where FeCl₃ and Atlasep 105C were added and mixed. The flocculated river water overflowed to the other setting tank for further clarification. This clarified water was then pumped through the multi-media filters and the activated carbon filters and then back to the river. No tests were conducted on the carbon column effluent since work performed in 1972 had indicated that the effluent quality from this system was more than adequate for discharge back to the river. Performance data from 1972 is summarized in Figure 12.

Sludge from the presettling tank and the final settler was pumped to a 18,925 L (5000 gal) tank trailer. This trailer served as a "day tank" and permitted some thickening prior to ultimate disposal in a landfill. The supernatant from the day tank was decanted back to the reaction tank each morning in order to reduce the sludge hauling costs.

During the cleanup operation, a crew of 10 men was used, including:

- 1 - Project engineer
- 1 - Sweeper operator

- 1 - Pump and valve operator
- 1 - Presettler operator
- 2 - Chemical technicians - sampling and analysis
- 2 - Treatment system operators
- 1 - Hose handler

When both sweepers were on line simultaneously, the chemical technicians were used to operate the second sweeper.

Due to materials shortages, River Sweeper II was not available for use until the last month of the project. The design objectives were achieved and the sweeper proved to be much more flexible and easier to use than Sweeper I. During the period when both sweepers were on line it was possible to clean approximately 33.53 to 38.10 lineal meters (110 to 125 lineal feet) per day or 185.8 to 232.25 m² (2000 to 2500 ft²).

During the cleanup phase, 5,828,900 L (1,540,000 gal) of river muds were processed through the system. Grit collected in the presettler amounted to 45,798.5 L (12,100 gal) and liquid sludge was 692,644 L (183,000 gal). The thickened liquid sludge varied from 3% to 55% solids with the estimated average concentration being 35% solids.

Immediately following the cleaning of a reach of river, the section was sampled and analyzed to insure that the residual concentration was less than the 5,000 mg/kg level established as the level adequate to protect incumbent and potential aquatic fauna. In those cases where the residual concentrations exceeded the standard, the section was recleaned until the standard was achieved. The residual concentrations after cleanup are also given in Table 8.

Within 45 days following the cleanup, sightings of bluegills, largemouth bass, black bullheads, white suckers, and muskrat and turtles were made in an area that previously had been totally devoid of higher organisms.

Because of the extreme variability in the contaminant concentration, it is difficult to accurately report the results of the cleanup effort. For the 1231.39 m (4040 ft) that were cleaned, the mean concentration before cleanup was 6,911 mg/kg and after cleanup was 1,670 mg/kg, indicating a 76% removal of contaminants. The vertical and horizontal distribution of this contaminant is such that though the removal percentage is quite good, the data could be skewed depending on the exact sample location.

There definitely appears to be a need for basic study to develop statistically reliable techniques for sampling bottom sediments.

Table 8. RIVER BOTTOM MUDS - HEXANE EXTRACTABLE CONCENTRATIONS
BEFORE AND AFTER CLEANING LITTLE MEMPHIS RIVER

Station meters feet	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
--					
15.24	Brown Deer Road	1	<1,190		
30.48		2	<1,220		
45.72		3	<1,400		
56.99		4	12,700		
	R.R. Trestle	--	--		
60.96		5	8,800		Bankline cleaning started
76.20		6	10,900		
91.44		7	1,800		
106.68		8	3,300		
121.92		9	2,900		
137.16		10	2,700		
148.43		--	--	2360	
152.40		11	1,400	--	
167.64		12	1,900	0	
182.88		13	1,900		
198.12		14	10,300		Bottom cleaning started
213.36		15	3,900	2,150	
228.60		16	4,000	3,090	
243.84		17	10,500		
259.08		18	3,800		
274.32		19	1,900	2,020	
289.56		20	2,100		
304.80		21	10,300	2,150	
320.04		22	2,000		
335.28		23	1,900	2,250	

(Continued)

Table 8 (Continued).

Station meters	Foot	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
350.52	1150		24	1,900		
365.76	1200		25	3,280	2,200	
381.00	1250		26	3,280		
396.24	1300		27	3,390	0	
411.48	1350		28	4,760		
422.76	1387		--	--		
426.72	1400		29	10,000	1,240	
441.96	1450		30	15,910		
457.20	1500		31	18,180	2,200	
472.44	1550		32	12,200		
487.68	1600		33	9,440	1,940	
502.92	1650		34	10,870		
518.16	1700		35	10,000	4,720	
533.40	1750		36	10,200		
548.64	1800		37	18,500	930	
563.88	1850		38	8,930		
579.12	1900		39	20,410	2,960	
594.36	1950		40	3,080		
609.60	2000		41	1,850	1,970	
624.84	2050		42	1,700		
640.08	2100		43	2,220	970	
655.32	2150		44	4,260		
670.56	2200		45	2,170	0	
685.80	2250		46	3,130		
701.04	2300		47	2,570	2,970	
716.28	2350		48	4,760		
731.52	2400		49	2,170	3,220	

(Continued)

Table 8. (Continued)

Station meters	Feet	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
746.76	2450		50	3,920		
762.00	2500		51	2,500	4,960	
772.24	2550		52	4,550		
792.48	2600		53	3,330	879	
807.72	2650		54	4,870		
822.96	2700		55	2,280	--	
838.20	2750		56	7,140		
853.44	2800		57	13,510	0	
868.68	2850		58	13,160		
883.92	2900		59	11,630	1,540	
899.16	2950		60	10,420		
914.40	3000		61	4,540	1,510	
929.64	3050		62	5,880		
967.74	3175		63	11,360		
1005.84	3300		64	4,260	0	
1043.94	3425		65	6,670	1,290	1036.32 m 3400 ft
1082.04	3550		66	12,200	660	1066.80 m 3500 ft
1120.14	3675		67	11,630	0	1097.28 m 3600 ft
1158.24	3800		68	14,700	1,730	
1196.34	3925		69	16,670	2,020	1188.72 m 3900 ft
1234.44	4050		70	5,560	1,400	1219.20 m 4000 ft
1272.54	4175		71	5,130	1,590	1280.16 m 4200 ft
1310.64	4300		72	2,270	0	
1363.98	4475		73	16,130	3,340	1341.12 m 4400 ft
1385.92	4547		74	2,630	0	1371.60 m 4500 ft
1402.08	4600		75	14,290		
1424.94	4675		76	4,550	7,740	
1447.80	4750		77	43,480		

(Continued)

Table 8. (Continued)

Station meters	feet	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
1470.66	4825		78	4,080		
1492.53	4900		79	4,350		
1516.38	4975		80	2,380		
1531.62	5025		81	2,330		
1554.48	5100		82	23,260		
1577.34	5175		83	2,630		
1600.20	5250		84	12,500		
1623.06	5325		85	2,220		
1645.92	5400		86	9,380		
1668.78	5475		87	2,780		
1691.64	5550		88	5,560		
1714.50	5625		89	2,440		
1737.36	5700		90	30,300		
1760.22	5775		91	2,330		
1783.08	5850		92	13,890		
1805.94	5925		93	23,810		
1828.80	6000		94	12,200		
1851.66	6075		95	0		
1859.28	6100		96	0		
1866.90	6125		97	3,770		
1889.76	6200		98	1,960		
1912.62	6275		99	0		
1935.48	6350		100	0		
1958.34	6425		101	0		
1981.20	6500		102	0		
2004.06	6575		103	0		
2026.92	6650		104	0		
2049.78	6725		105	0		

R.R. Trestle

Bradley Road
1931.52 m
(6337 ft)

(Continued)

Table 8. (Continued)

Station meters	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
2072.64	6800	106	1,450		
2095.50	6875	107	0		
2118.36	6950	108	0		
2141.22	7025	109	0		
2164.08	7100	110	0		
2186.94	7175	111	3,280		
2209.80	7250	112	0		
2232.66	7325	113	0		
2255.52	7400	114	0		
2278.38	7475	115	0		
2324.10	7625	116	0		
2346.96	7700	117	0		
2369.82	7775	118	0		
2392.68	7850	119	1,520		
2415.54	7925	120	0		
2423.16	7950	121	0		
2438.40	8000	122	5,460		
2461.26	8075	123	0		
2484.12	8150	124	0		
2506.98	8225	125	0		
2529.84	8300	126	0		
2552.70	8375	127	0		
2575.56	8450	128	0		
2598.42	8525	129	0		
2621.28	8600	130	1,750		
2644.14	8675	131	0		
2667.00	8750	132	1,670		
2689.86	8825	133	3,130		

(Continued)

Table 8. (Continued)

Station meters	Feet	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
2712.72	8900		134	1,540		
2735.58	8975		135	2,860		
2758.44	9050		136	1,410		
2781.30	9125		137	2,890		
2815.74	9238		138	0		
2850.18	9351		139	4,270		
2884.63	9464		140	0		
2919.07	9577		141	0		
2953.51	9690		142	4,610		
2987.95	9803		143	1,590		
3021.48	9913		144	3,220		
3056.84	10029		145	0		
3091.28	10142		146	1,510		
3155.72	10255		147	3,450		
3160.17	10368		148	0		
3194.61	10481		149	0		
3229.05	10594		150	3,720		
3263.49	10707		151	1,730		
3297.94	10820		152	0		
3332.38	10933		153	1,590		
3366.82	11046		154	1,790		
3401.26	11159		155	0		
3435.71	11272		156	0		
3474.72	11400		157	6,790		
3505.20	11500		158	0		
3535.68	11600		159	1,640		
3566.16	11700		160	3,520		
3575.30	11730		161	1,420		

(Continued)

Table 8. (Continued)

Section meters	Foot	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
3584.45	11760		162	3,330		
3593.59	11790		163	5,370		
3602.74	11820		164	1,970		
3611.88	11850		165	0		
3621.02	11880		166	3,720		
3630.17	11910		167	1,560		
3639.31	11940		168	0		
3648.46	11970		169	3,720		
3657.60	12000		170	5,800		
3666.74	12030		171	2,890		
3675.89	12060		172	1,640		
3685.03	12090		173	8,600		
3695.18	12120		174	1,930		
3703.32	12150		175	2,980		
3712.46	12180		176	3,330		
3721.61	12210		177	1,930		
3730.75	12240		178	0		
3739.90	12270		179	0		
3749.04	12300		180	0		
3758.18	12330		181	1,700		
3767.33	12360		182	0		
3776.47	12390		183	3,120		
3785.62	12420		184	3,280		
3794.76	12450		185	0		
3803.90	12480		186	0		
3813.05	12510		187	0		
3822.19	12540		188	0		

(Continued)

Table 8 (Continued)

Station meters	feet	Location	Sample No.	Before cleaning estimated oil content, mg/kg	After cleaning estimated oil content, mg/kg	Comments
3631.33	12570		189	0		
3840.48	12600		190	0		
3849.62	12630		191	0		
3858.77	12660		192	0		
3867.91	12690		193	0		
3877.06	12720		194	0		
3886.20	12750		195	1,760		
3895.34	12780		196	4,200		
3904.49	12810		197	0		
3913.63	12840		198	5,280		
3922.78	12870		199	0		
3962.40	13000		200	1,920		
3971.54	13030		201	1,790		
3977.64	13050		202	7,160		
3986.78	13080		203	1,790		
3995.93	13110		204	0		
4005.07	13140		205	0		
4014.22	13170		206	10,070		
4023.36	13200		207	1,490		Bank line cleaning terminated
		End Point				

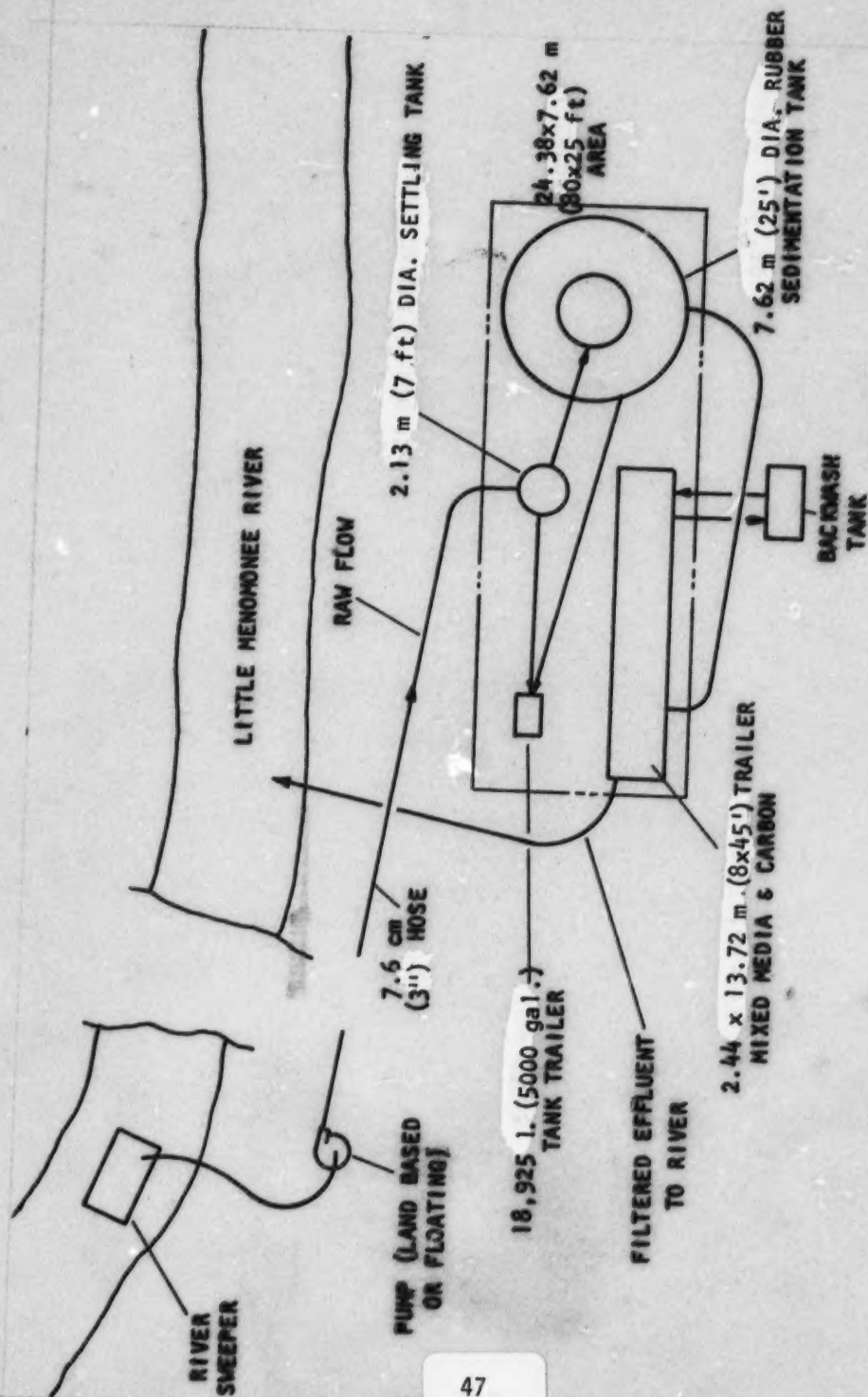


Figure 11. Typical mud retrieval & treatment system setup

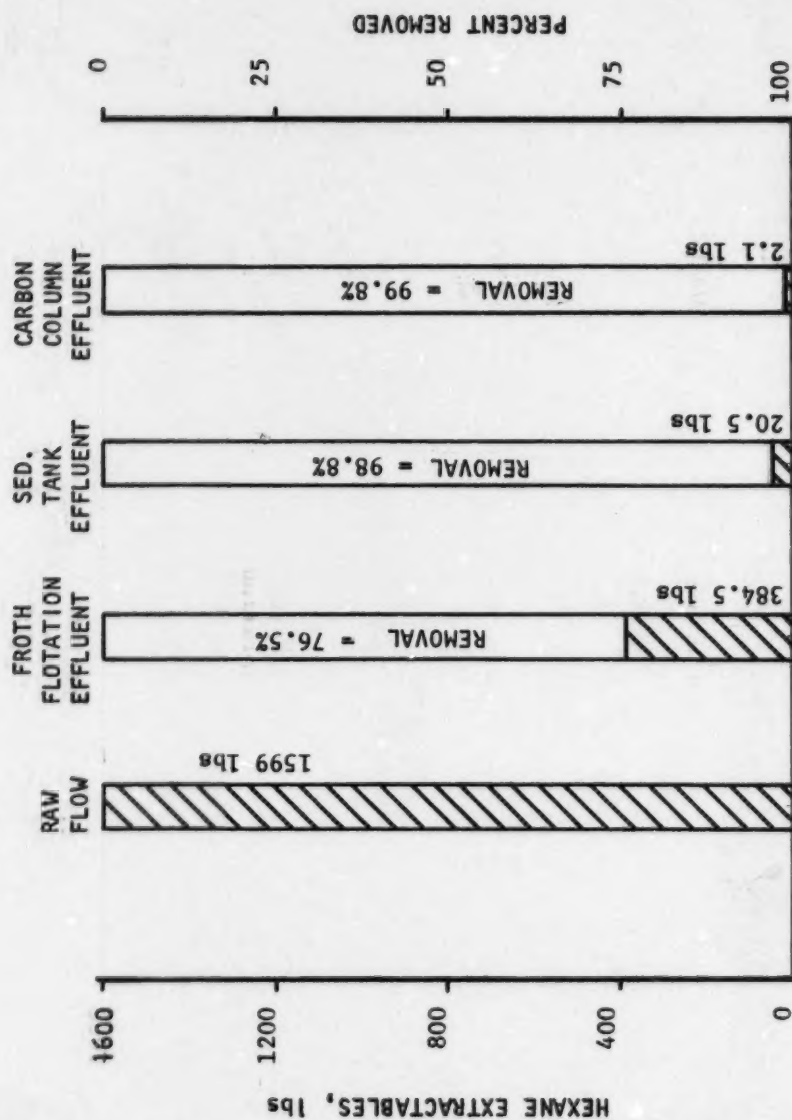


Figure 12. Hexane extractable removals.

SECTION 7

OPERATING PROBLEMS AND RECOMMENDATIONS FOR FUTURE CLEANUPS

The existence of toxic or hazardous materials in watercourses is generally the result of either one time accidental spills or a continuous discharge over long periods of time. Although the first case can cause serious environmental damage, if the cleanup is implemented within a very short period, the spread of materials can generally be contained within a reasonably small area.

The long-term, continuous discharge presents a much more difficult problem with regard to cleanup since the hazardous materials are spread out over a large area. In the case of the Little Menomonee, the pollutants were spread out over 8.05 km (5 miles) of stream, into the stream bank and to depths of 0.9 to 1.2 m (3 to 4 ft) in the stream bottom for some locations.

The removal of pollutants from the bottoms of streams is a most difficult task. Ideally large dredging equipment could be used to dredge contaminated muds with a minimum of operating problems. However, the small size of streams such as the Little Menomonee precludes use of large dredges even if adequate treatment capacity (63.09 to 315.45 L/s [1000 to 5000 gpm]) could be provided.

In the case of the Little Menomonee, a small dredge (6.3 L/s [100 gpm]) was utilized which could be matched to a transportable treatment system. Use of a small dredge, however, presents numerous problems of pluggage and equipment damage from underwater obstacles (see operating log, Table 9).

Based on observations made during the Little Menomonee study, it appears that a number of alternatives exist for different problems.

1. For small or large streams in which the pollutant is not interspersed with the bottom muds, a small hydraulic dredge such as used on the Little Menomonee can be coupled with a transportable system to provide a satisfactory means of retrieval and treatment.
2. For small streams where the contaminant is interspersed with the bottom muds to any substantial depth (15.24 cm [6 in.]) the stream, if possible, should be dammed up or diverted and the pollutant removed by mechanical means such as rubber tired front end loaders or bulldozers.

3. For large waterbodies where the contaminant is interspersed with the bottom muds to a depth of greater than 15.24 cm (6 in.), it will be necessary to utilize a relatively large dredge to pump the contaminated muds to a storage pond and/or treatment system.

The system used for the Little Menomonee operation appeared to be an adequate method for removing contaminated bottom muds to a depth of approximately 15.24 cm (6 in.). In those cases where the muds were contaminated to depths greater than 15.24 cm (6 in.) the frequency of line clogs and equipment breakdowns greatly impeded progress and other methods should be investigated.

Table 9. OPERATIONS LOG
July 25 to August 10, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed,		Sludge volume removed	
				liters	gallons	liters	gallons
M	23	10	Final setup and adjustments to equipment before operations				
T	24	10	Setup and adjustment to equipment cont'd.	24,413	6,450		
W	25	10	First day of operations				
Th	26	10	River too low to operate, sandbag dam at Bradley Road	7,305	1,930		
F	27	10	Good day; ran dilution water between sweeper moves	157,645	41,650		
S	28	10	Moved pumps; backwashed filters, decanted holding tank	89,136	23,550		
S	29						
M	30	10	Burst 7.6 cm (3") hose; problems w/plugged lines	128,756	34,020		
T	31	10	Coupling problem w/hydraulic pump	119,416	31,500		
W	1	10	New coupling parts installed; backwashed filter				
Th	2	10	Plugged sweeper mase, burst hose, backwashed filter	57,986	15,320	17,032	4,500
F	3	10	Railroad spike jammed pump, new pump used	130,582	34,500		
S	4			100,113	26,450		
S	5						
M	6	10	Unplugged presettler, replumbed pillow tank, backwashed filters, removed solids	143,981	38,040		
T	7	10	High solids loading, numerous shutdowns	117,143	30,950		
W	8	10	Removed mud, moved pumps, rain in p.m.	16,199	4,280	34,065	9,000
Th	9	10	Rainout - no work	0	0	17,032	4,500
F	10	10	Good day; changed method of moving Sweeper I	92,278	24,380		

(Continued)

Table 9. (Continued)
August 11 to September 10, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed, Titters		Sludge volume removed, Titters	
				gallons	gallons	gallons	gallons
S	11	7	Plugged mast and in: tall vac. gage; sweeper operator	37,093	9,800		
S	12						
M	13	10	Pump mud out of reaction tank	113,176	29,900		
T	14	10	Broken coupling, worn through suction hose water in gas	24,337	6,430		
W	15	10	Sweeper to Moss Bridge 9:30, in & out of water by 3 pm	75,737	20,010		
Th	16	10	Wear plate broken, burst hose, plugged presettler	97,425	25,740		
F	17	10	Moved pumps, filters loaded	48,902	12,920		
S	18	10	Began equipment move - 10 am	23,731	6,270	17,032	4,500
S	19						
M	20	10	Continued equip. move, decanted sedimentation tank	36,638	9,680	17,031	4,500
T	21	9	Removed built up sludge	0	0		
W	22	10	Replaced hyd. engine moved presettler & spills trailer	0	0		
Th	23	10	Rained steady all day	0	0	17,031	4,500
F	24	10	Broken sweeper spud; intermittent rain	53,368	14,100		
S	25						
S	26						
M	27	8	Very hot - 99°F; broke another sweeper leg; plugs	56,018	14,800		
T	28	8	Continued hot; repaired spud, moved pumps	71,044	18,770		
W	29	8	Clogs, (wood chips), influent dirty; cont'd hot				
Th	30	9	Part rain; weed plugs; presettler plugged	66,502	17,570		
F	31	10	Broken hyd. pump fittings	38,342	10,130		
S	1			94,095	24,860	17,032	4,500
S	2						
M	3		Labor Day				

(Continued)

Table 9 (Continued)
August 11 to September 10, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed,		Sludge volume removed	
				Titers	gallons	Titers	gallons
T	4	10	Rained out; decanted sedimentation tank	9,500	2,510		
W	5	10	Fix hyd. pack; head broke off mast	32,702	8,640		
Th	6	10	No access due to rain; system mud loaded	68,622	18,130		
F	7	10	Broken hyd. fittings; plugs in presettler	44,890	11,860		
S	8	5	System mud loaded; broke pump fitting	27,895	7,370		
S	9						
M	10	10	Cutterhead motor problems, sludge pump out TOTAL LINEAL METERS - 320 (1050 ft)	73,958	19,540	17,032	4,500
September 11 to October 10, 1973							
T	11	10	Wear plate stud broke	95,760	25,300	17,032	4,500
W	12	10	Dirty filters; chem feeder check valve plugged	25,208	6,660		
Th	13	10	Change old wear plate; pump plugs	79,295	20,950		
F	14	10	Plugged presettler, hyd. package broke, sweeper hung up	54,163	14,310		
S	15	10	Repair coupling, mud buildup slower sweeper	64,534	17,050		
S	16	0	Rained all day	0	0		
M	17	2	No access to sludge tank; system full of mud	56,472	14,920		
T	18	10	Grit chamber installed; began graveling road	46,025	12,160	17,032	4,500
W	19	10	Good day due to "clean" tanks			17,032	4,500
Th	20	10	Rained half day; broke suction hose	26,930	7,115		
F	21	7	Bad "0" ring on pump; moved pump	43,092	11,385		
S	22	10	Plugged presettler	43,338	11,450	17,032	4,500
M	24	10					

(Continued)

Table 9. (Continued)

September 11 to October 10, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed,		Sludge volume removed	
				Titers	gallons	Titers	gallons
T	25	2	Rained all day	0	0		
W	26	10	Hydraulic power package problems	52,649	13,910		
Th	27	10	No access for sludge pickup	62,831	16,600		
F	28	2	Rained all day	0	0		
S	29	8	Pump moved	54,882	14,500		
M	1	10	No sludge pickup; more gravel; operations slow	61,165	16,160		
T	2	10	Coupling broke; crushed rock installed	79,182	20,920		
W	3	10	Sludge pickup; good day	78,500	20,740		
Th	4	10	Two sludge pickups; rained	18,925	5,000	17,032	4,500
F	5	10	Two sludge pickups; good day	78,728	20,800	34,065	9,000
S	6	8	Broken taper lock coupling	42,505	11,230	34,065	9,000
S	7	0					
M	8	10	Fixed coupling; generator didn't start - fixed; pumped sludge	0	0	17,032	4,500
T	9	10	Began dismantling equipment good day	68,546	18,110	17,032	4,500
W	10	10	Equipment move			34,065	9,000
			TOTAL LINEAR METERS - 252.94: (830 ft)				
October 11 to November 10, 1973							
Th	11	10	Equipment moved to Site III				
F	12	10	426 meters (1400 ft) of hose from Sweeper I to presettler				
S	13	8	New power cords, booster pump, etc				
M	15	10	Finished setup, problem w/pump 1 engine	40,007	10,570		
T	16	10	Fixed chock plate; launched part of Sweeper II	63,133	16,680		

(Continued)

Table 9. (Continued)
October 11 to November 10, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed, Titters		Sludge volume removed Titters	
				gallons		gallons	
W	17	10	Hyd. power package maintenance, snapped welds on Sweeper II	67,145	17,750		
Th	18	10	Snapped stud on pump case; borrowed stud, snapped again	35,351	9,340		
F	19	9	Repaired studs; assembled Sweeper II	59,083	15,610		
S	20						
S	21						
M	22	10	Both sweepers operating; good day	87,130	23,020	17,032	4,500
T	23	10	Generator not working; bad condenser	151,059	39,910		
W	24	11	Modified new sweeper; excellent day	179,863	47,520		
Th	25	10	Too much flow; fast mud buildup; good day	141,596	37,410	17,032	4,500
F	26	10	Sweepers bottomed; dam down	130,885	34,580	34,065	9,000
S	27						
S	28						
M	29	10	Too much mud; no sludge pickup due to closed dump; very slow, must let settle; alternating sweepers				
T	30	2	Hose and pump plugs	81,642	21,570	17,032	4,500
W	31	10	Steady rain	125,472	33,150		
Th	1	10	Bad "O" ring & wear plate on Sweeper II	0	0		
F	2	10	Steady drizzle in morning	107,191	28,320	34,065	9,000
S	3	9	To tie bridge	130,506	34,480		
S	4		Freeze	107,494	28,400		
M	5	2	Unseasonably cold - low 20's	0	0		
T	6	2	Cold; some maintenance performed	0	0		
W	7	2	Cold; some maintenance performed	0	0		
T	8	2	Cold; some maintenance performed	0	0		
F	9	2	Cold; some maintenance performed	0	0		
S	10			0	0		
S	11						
TOTAL LINEAL METERS - 385 (1175 ft)							

(Continued)

Table 9. (Continued)
November 12 to November 30, 1973

Day	Date	Hours worked	Problems, remarks, etc.	Volume processed, Titters	gallons	Sludge volume removed Titters	gallons
M	12	9	Repaired freeze damage, 5 valves & isolator	23,996	6,340		
T	13	9	Finished 22.9 m (75') upstream section and 15.3 (50') before tie bridge	38,531	10,180	34,065	9,000
W	14	9					
Th	15	9					
F	16	9	Drained system				
S	17	5	Started cleanup				
S	18						
M	19	10	Site & equipment cleanup; moved			51,097	13,500
T	20	10	Back to office				
W	21	8	Equipment back to subcontractors				
Th	29		Final sludge pickup by AA			17,032	4,500
F	30		Removed storage tank			9,462	2,500
TOTAL LINEAL METERS - 38.1 (125 ft)							

SECTION 8

COSTS

The costs of removing the creosote contamination from the Little Menomonee River was estimated for bankline and bottom cleaning and is shown in Table 10. The costs for capital equipment items are not included in the estimate.

These unit costs are considered high and reflect the problem of a "brute force" manual effort approach. These costs plus the 0.6 to 0.9 m (2 to 3 ft) depths of contaminated muds found in the upper reaches are the reasons for not completing the cleanup of the entire contaminated reach.

Table 10. CLEANUP COSTS

Item	Amount	
<u>Bankline cleaning</u>		
Labor	\$23,000	
Trucking	1,080	
	<u>\$24,080</u>	\$6,040/1000 lineal meters \$1,840/1000 lineal feet
<u>River bottom cleaning</u>		
Cost	\$123,975	
Length of river	1,230 lineal meters (4,040 lineal feet)	
Unit Cost	$\frac{\$123,975}{1230 \text{ m}}$	= \$100.79/lineal meters
	$\frac{\$123,975}{4040 \text{ ft}}$	= \$ 30.80/lineal feet
Estimated m ² =	9290	
Estimated ft ² =	100,000	
Unit Cost =	$\frac{\$123,975}{9290 \text{ m}^2}$	= \$13.35/m ²
	$\frac{\$123,975}{100,000}$	= \$1.24/ft ²

Some 1219+ lineal meters (4000+ lineal feet) of contaminated river bottom remain, plus the oxbow at Leon Terrace (Figure 13), which should be cleaned up should funds become available. This objective could be best accomplished by damming off the river north of the Brown Deer Road and using a rubber-tired tractor working in the river bottom to scoop out the muds.

Priority 1 - From bridge at 8451 N. 91st downstream to RR Trestle (152.4 m (500 ft) north of Bradley Road). Length: 522.4 m (1750 ft)

Priority 2 - 60.96 m (200 ft) from Calumet Bridge downstream to drainage culvert directly west of Dogwood. Length - 365.76 m (1200 ft)

Priority 3 - Stormwater drainage ditch north of Calumet including river downstream & upstream. Length: ditch 30.48 m (100 ft); river 76.2 m (250 ft)

Priority 4 - Begins at concrete foot bridge supports & upstream to mud flat. Length - 106.68 m (350 ft)

Priority 5 - Section begins 45.72 m (150 ft) south of Dogwood culvert. Length: 121.92 m (400 ft)

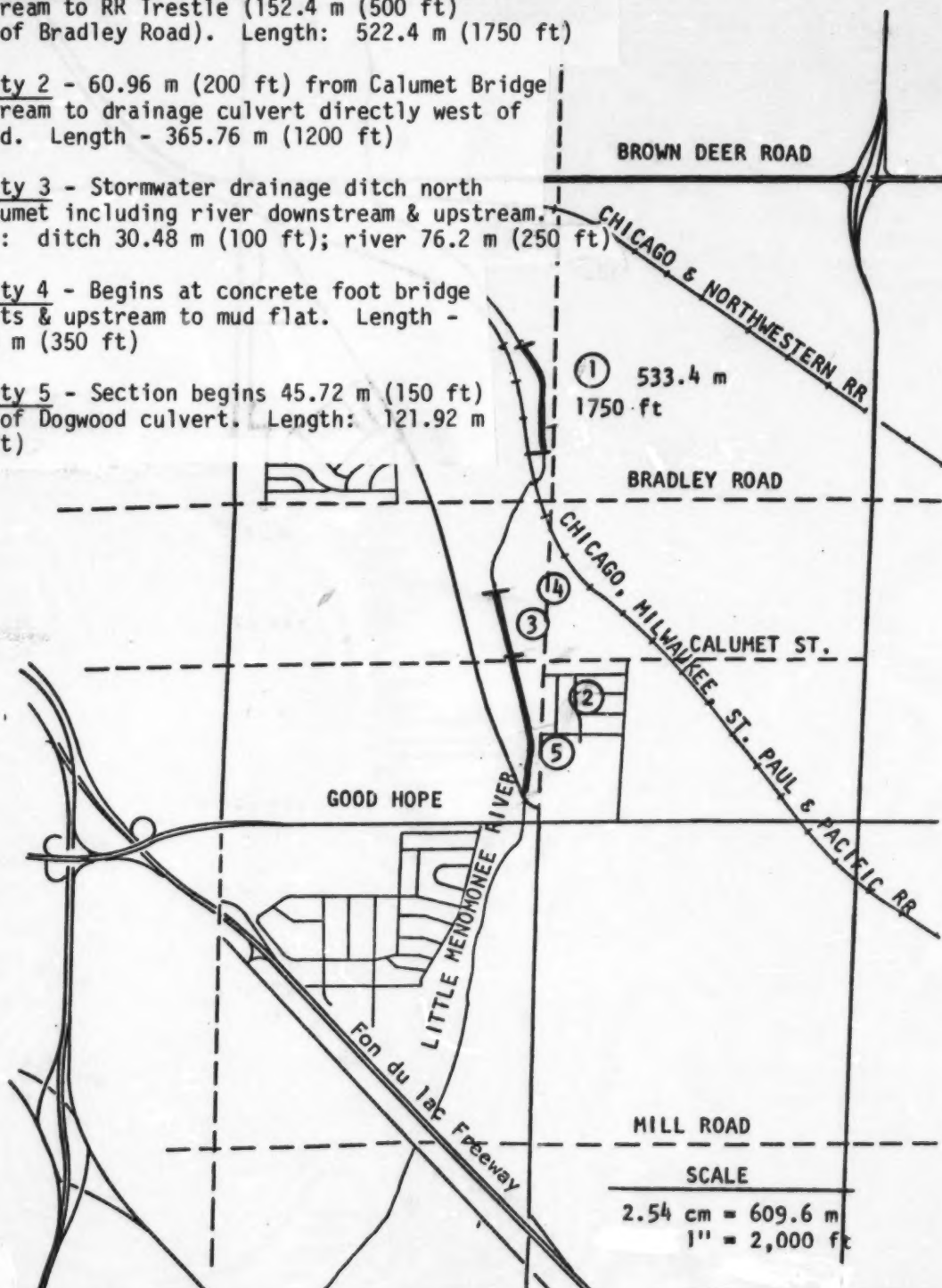


Figure 13. Priority locations

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